The Compact TIM (CTIM) Instrument

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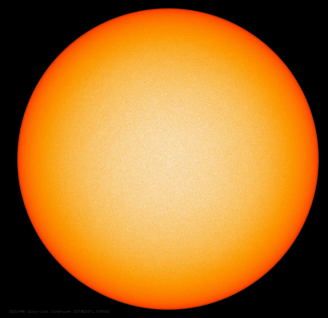
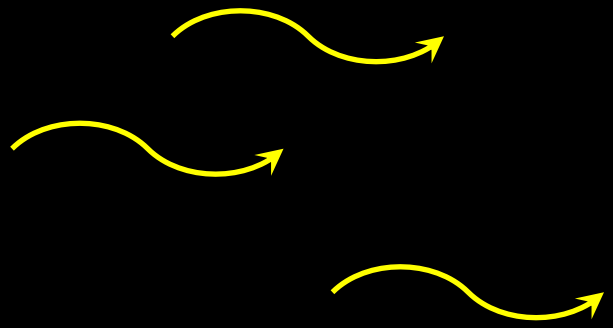
Total Solar Irradiance (TSI)

Total power from the sun onto the Earth

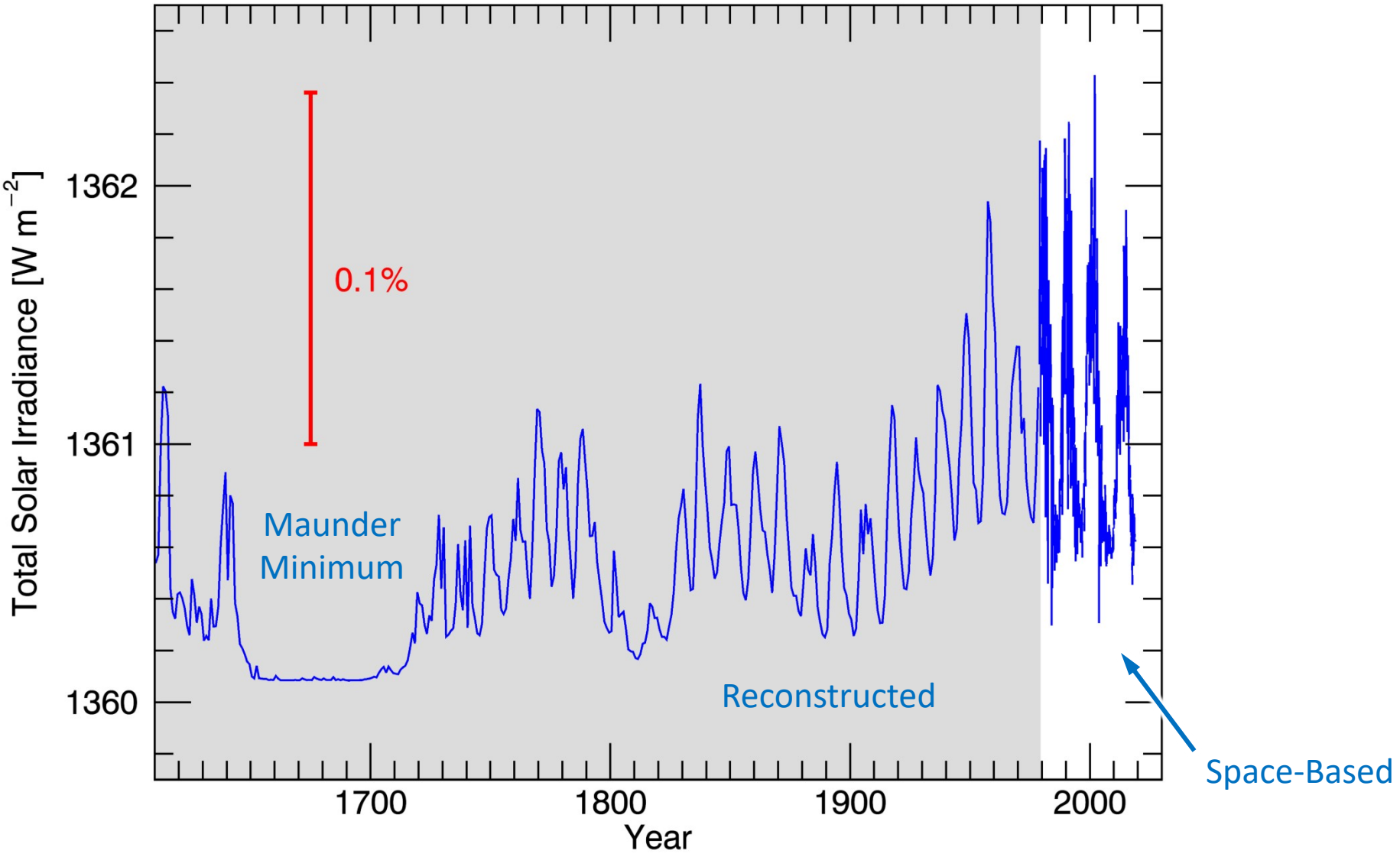
The input for Earth's climate

W m^{-2} @ 1 AU

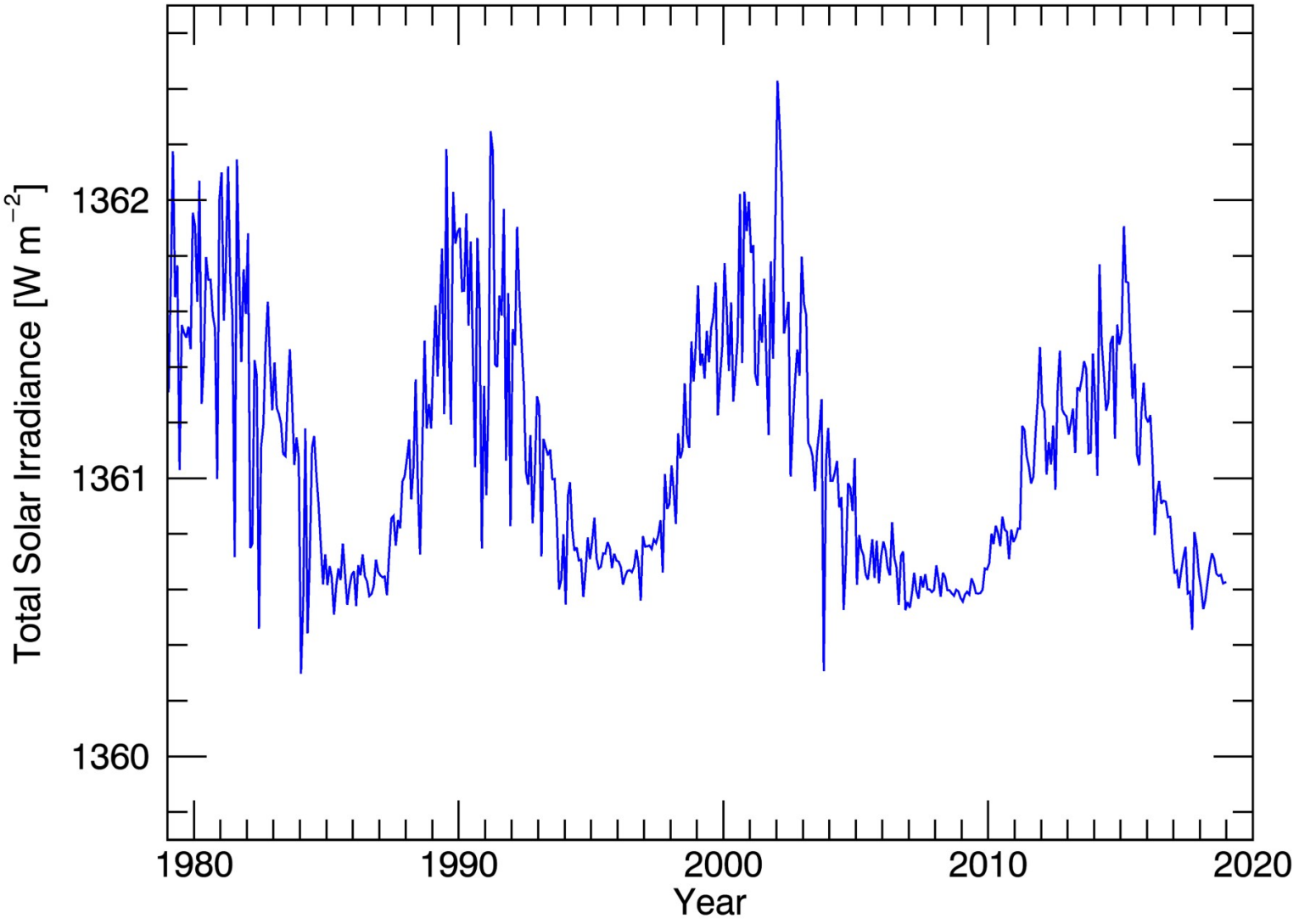




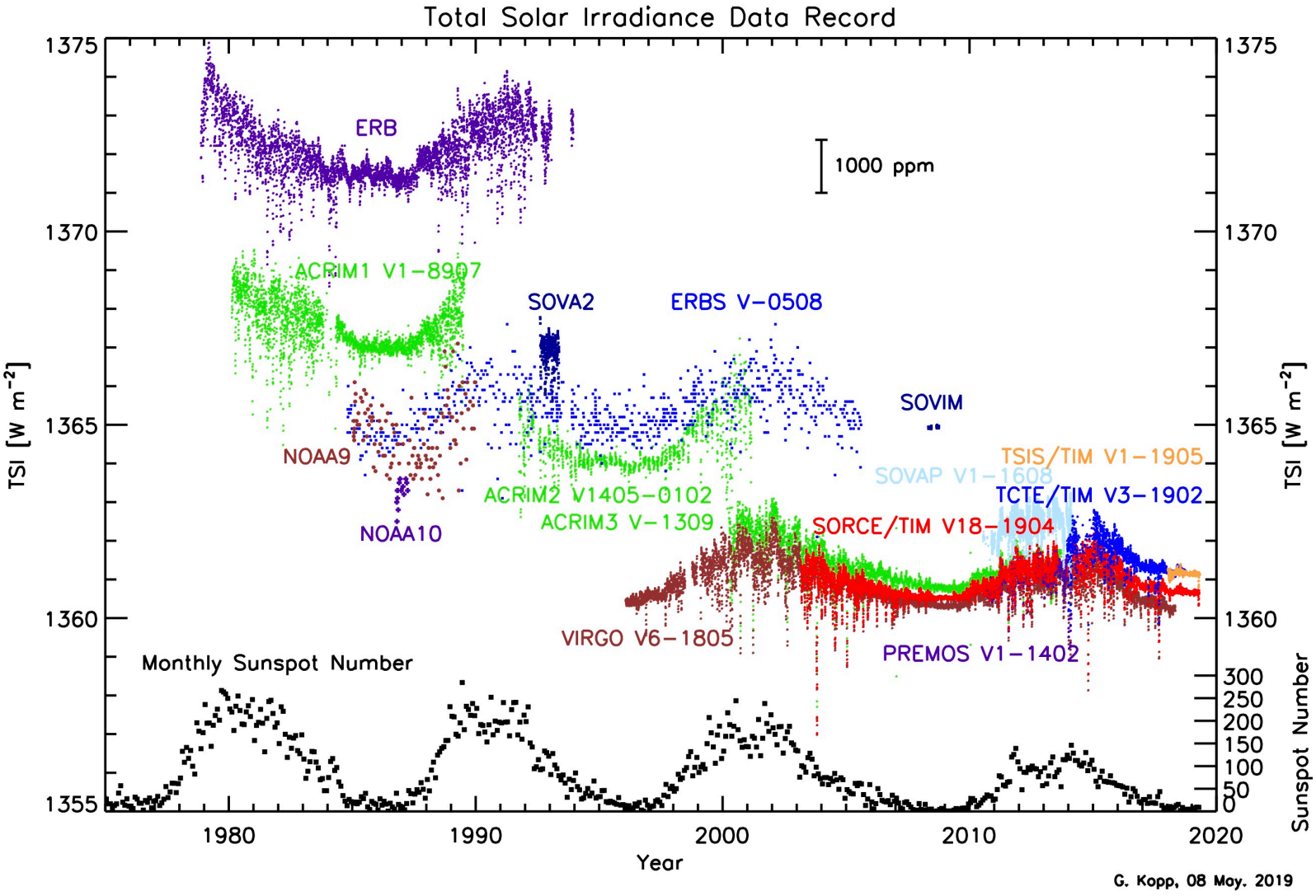
Long-Term TSI Variability



40-Years of Space-Based Measurements



Ensemble of TSI Space-Based Measurements

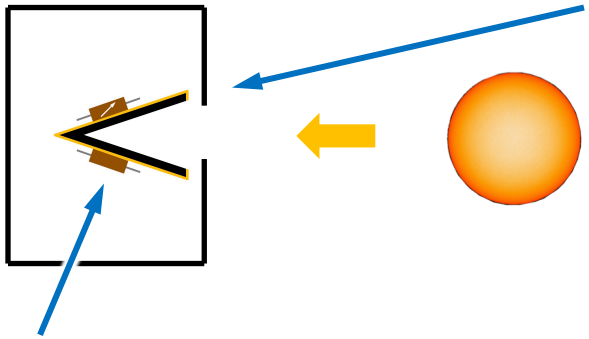


TSI Measurement

Measurement Requirements

- Wavelength range: 100 nm – 50 microns
- Accuracy: 0.01%
- Stability: 0.001%/year

Basic Instrument Design



Precision Aperture [m^2]

- Typically 5-8 mm diameter

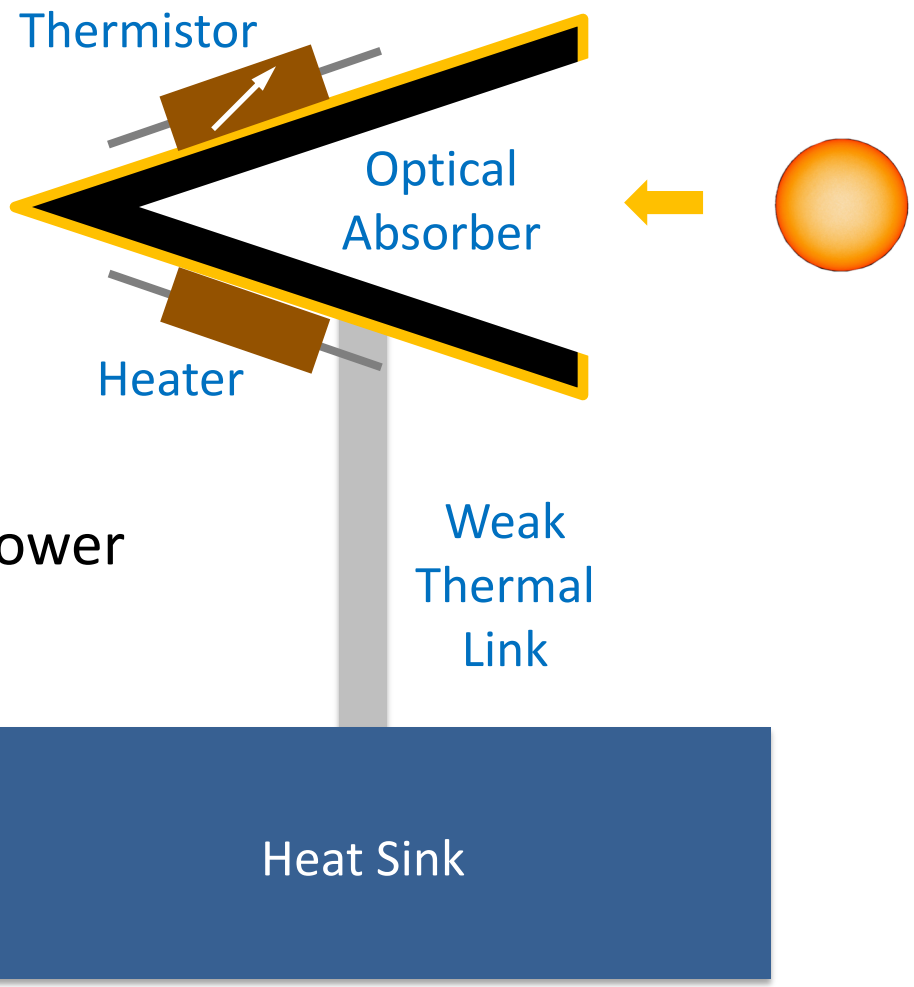
Detector [W]

- Bolometric (thermal)
- Typical Power Level: 26-68 mW

Detector: Electrical Substitution Radiometer

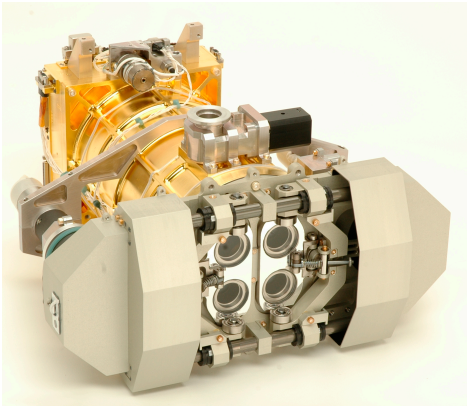
- Temperature measurement
  - ~1 μK noise level
- Heater maintains constant temperature
- Optical absorber collects incoming light
  - Black surface + cavity

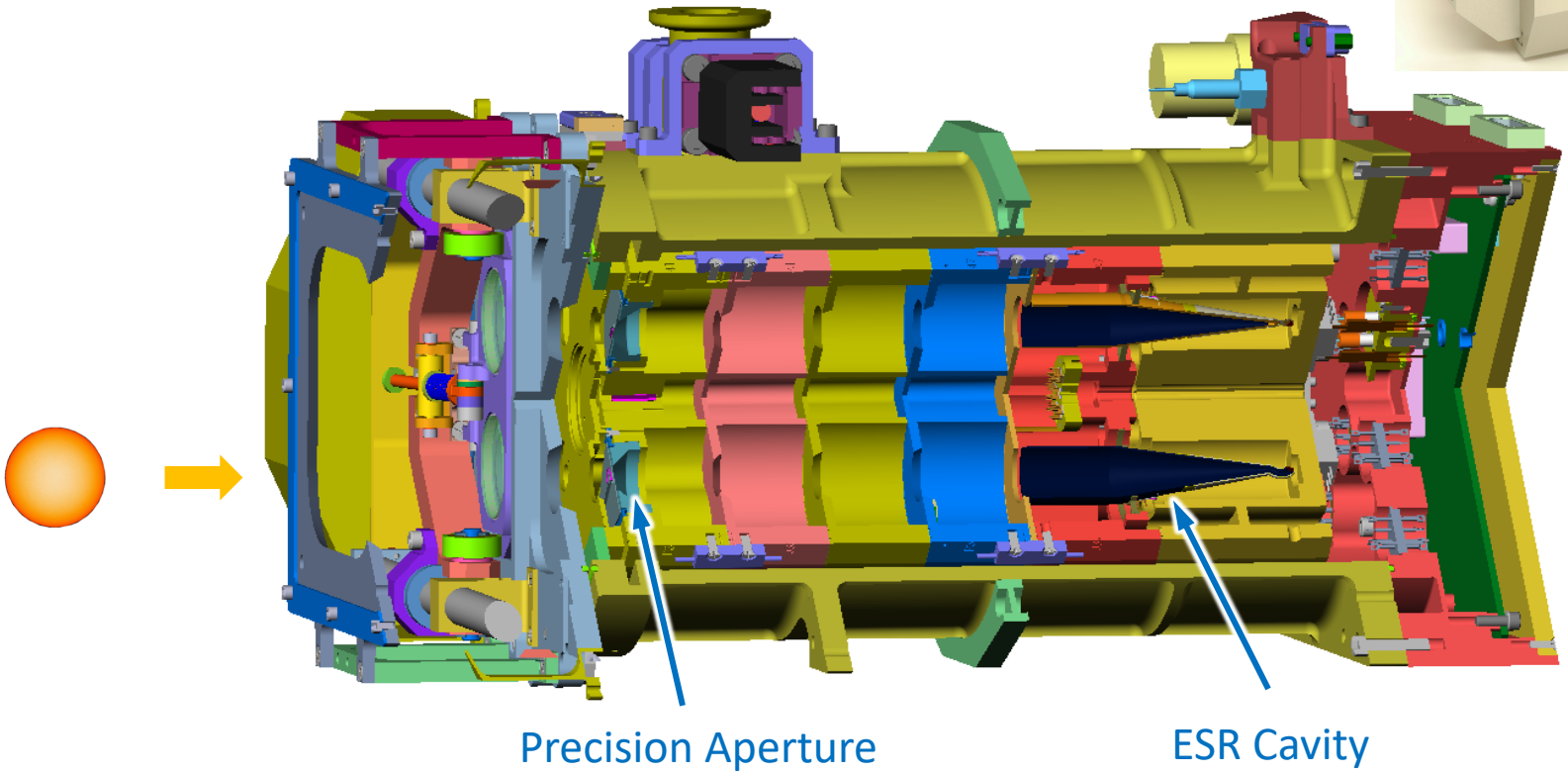
Optical power = Change in heater power



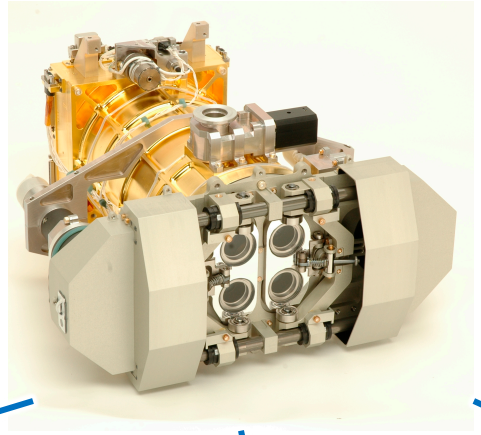
LASP TSI Instrument Heritage

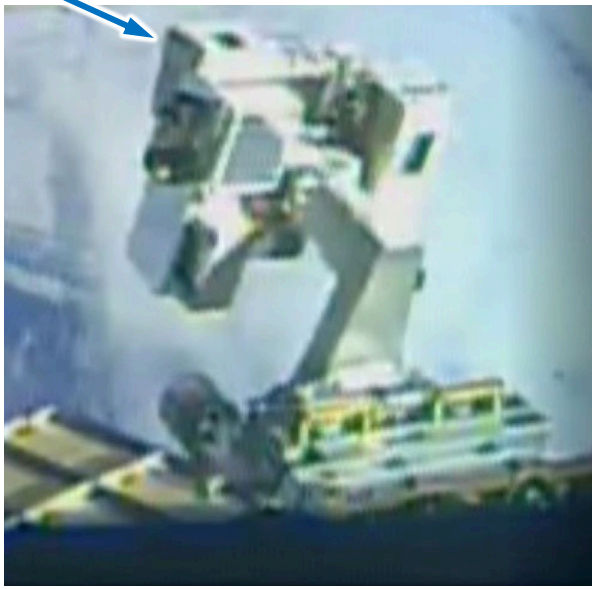
- SORCE Total Irradiance Monitor (TIM), Launched 2003
- TCTE TIM, Launched 2013
- TSIS TIM, Launched 2017
- Size: 29x17x30 cm, 7.3 kg





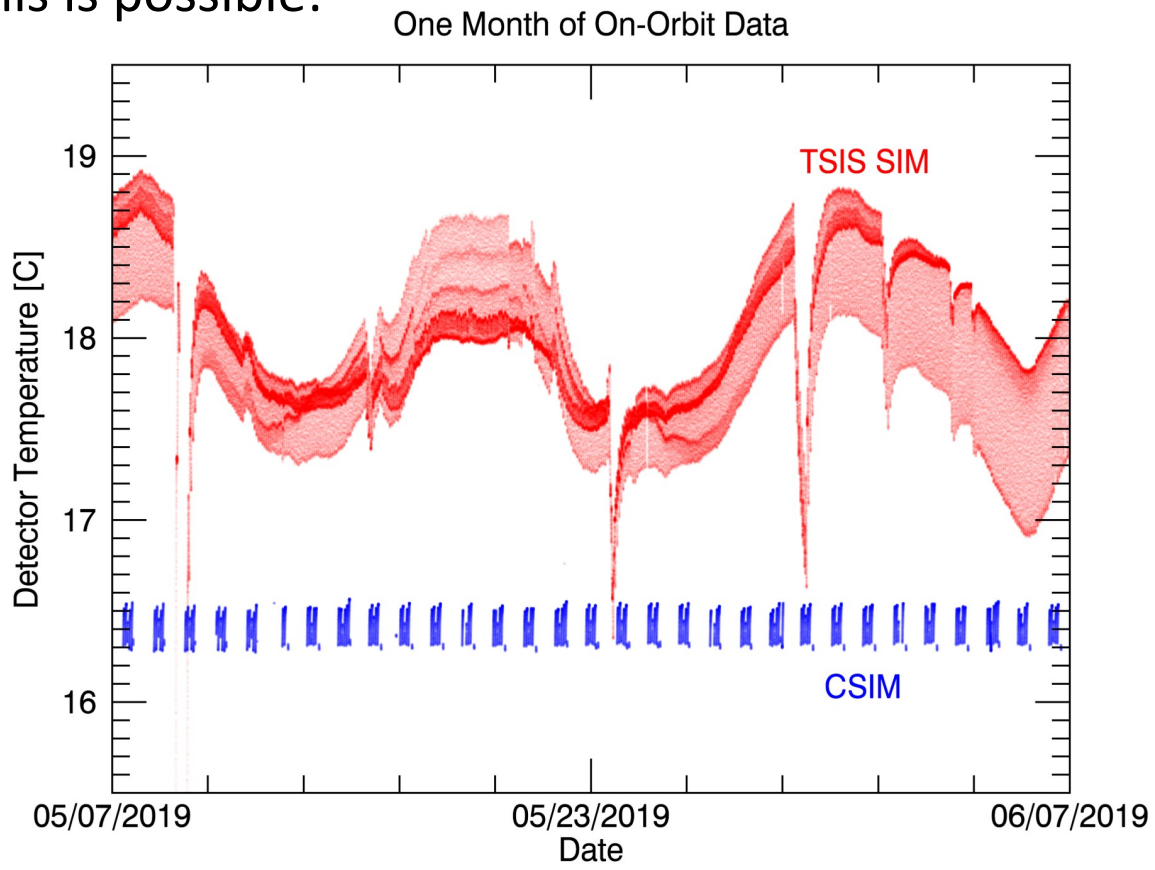
TSIS-TIM on ISS





Is TSI Measurement a Candidate for a CubeSats?

- **YES**: Lots of signal, small apertures, compact path-length
- But, need good temperature stability
  - CSIM has proven that this is possible:



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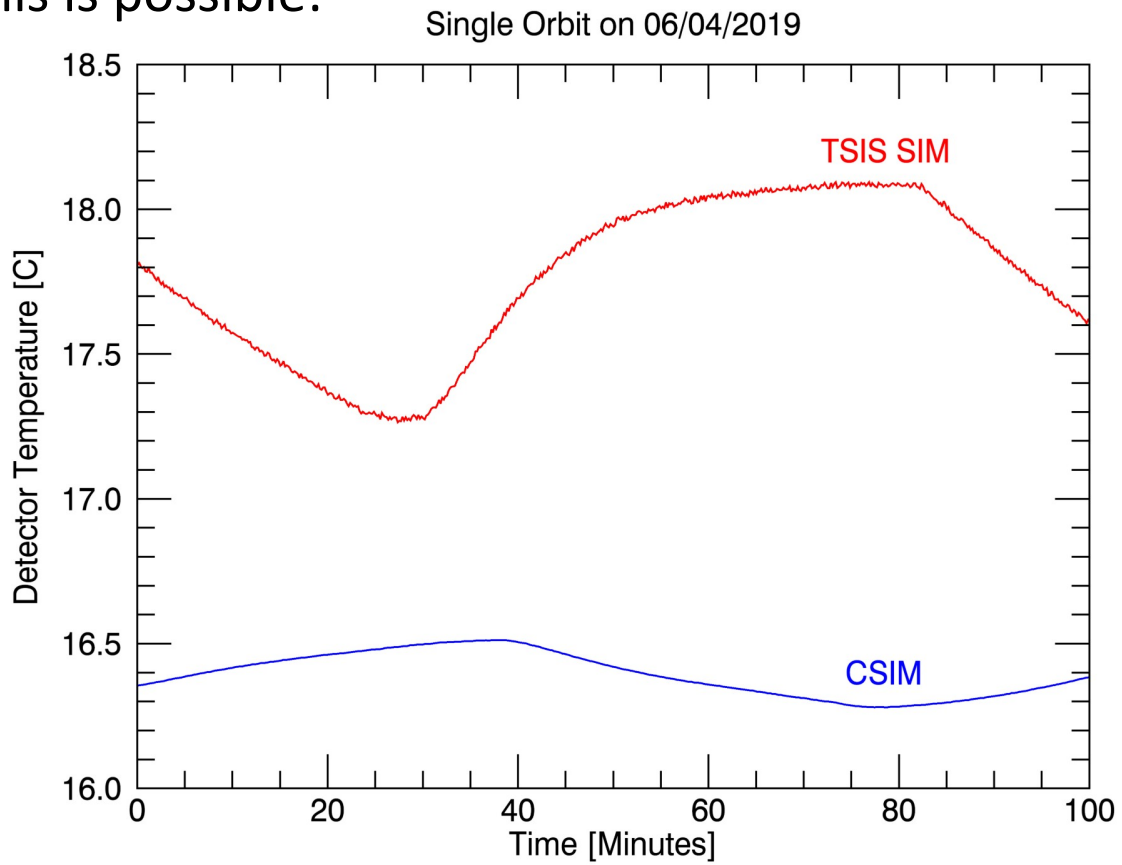
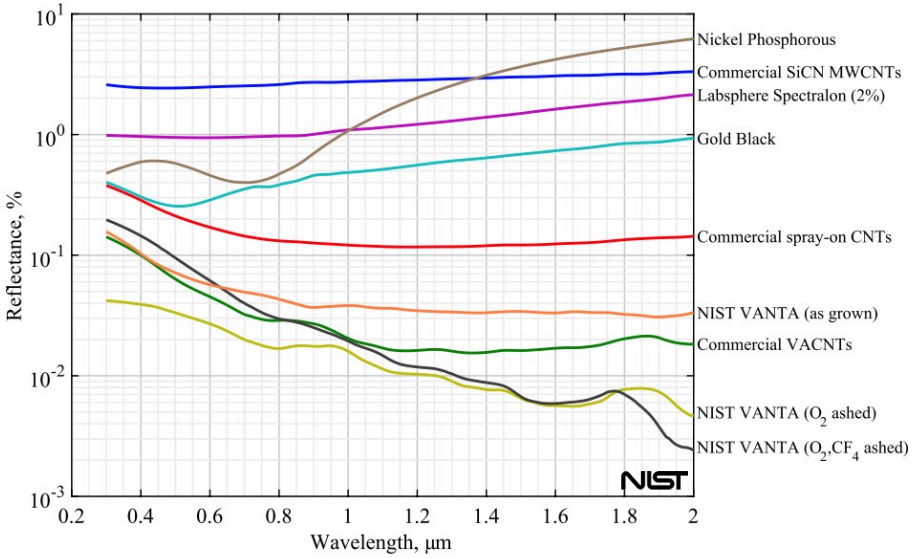


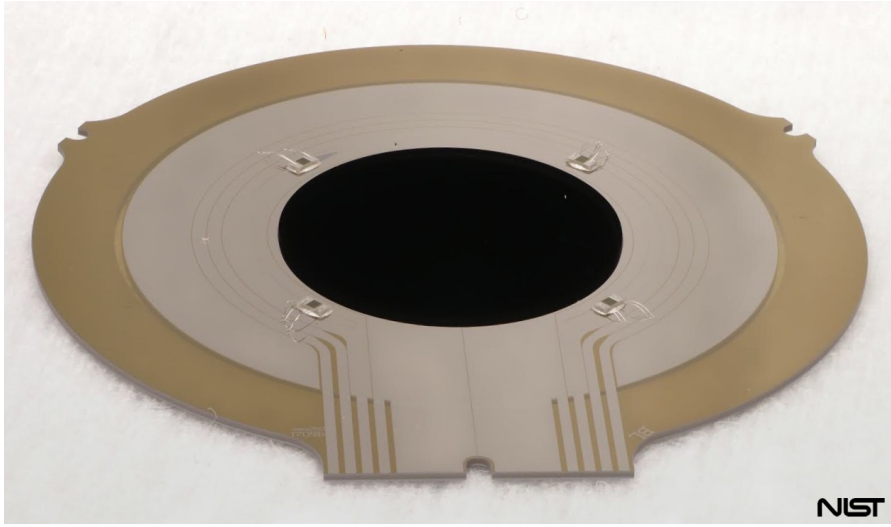
New Technology

- Not just smaller, using CubeSat as new technology testbed
- Key new technology: Silicon + Vertically Aligned Carbon Nanotubes
  - Microfabrication allows 2D fabrication with micron-level precision
  - Typical absorptance 99.9%
  - Developed with NIST Boulder

VACNTs are the *Blackest Black*



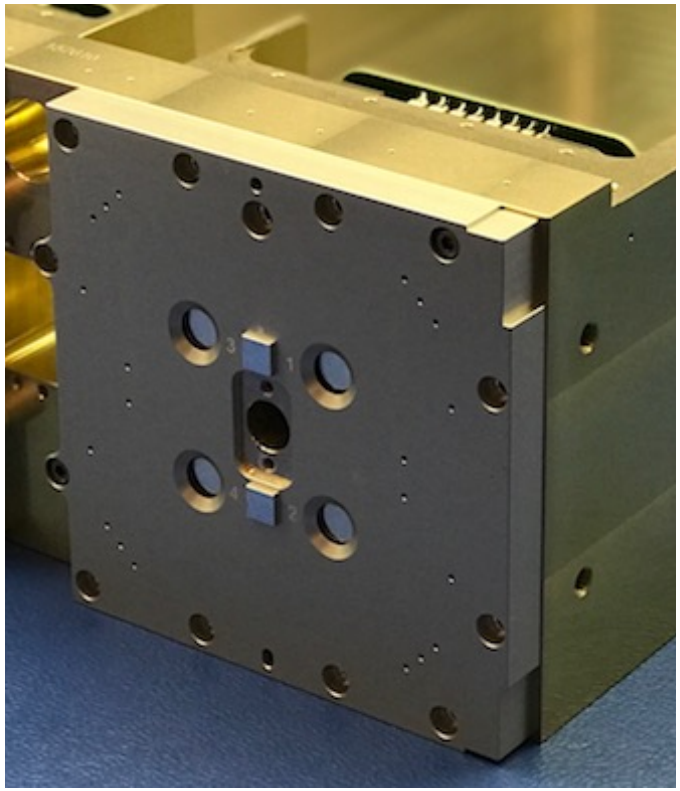
Prototype Detector



Compact Total Irradiance Monitor

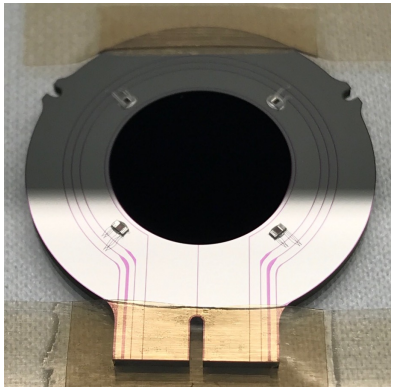
- CubeSat TSI instrument
- Reduce size, reduce cost relative to TIM
  - TIM Size: 29x17x30 cm, 7.3 kg
  - CTIM Size: 8x8x6 cm, 0.6 kg
- Meet TSI measurement requirements
- Include next-generation technology
  - Vertically aligned carbon nanotubes
  - Ion-etched precisions apertures
  - Powerful reprogrammable FPGAs

CTIM Detector Head

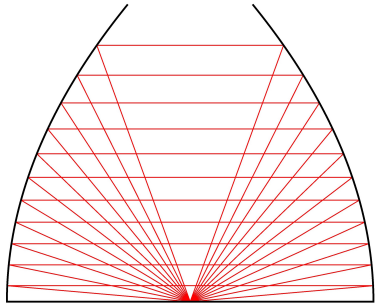


CTIM Detectors

Silicon Detector



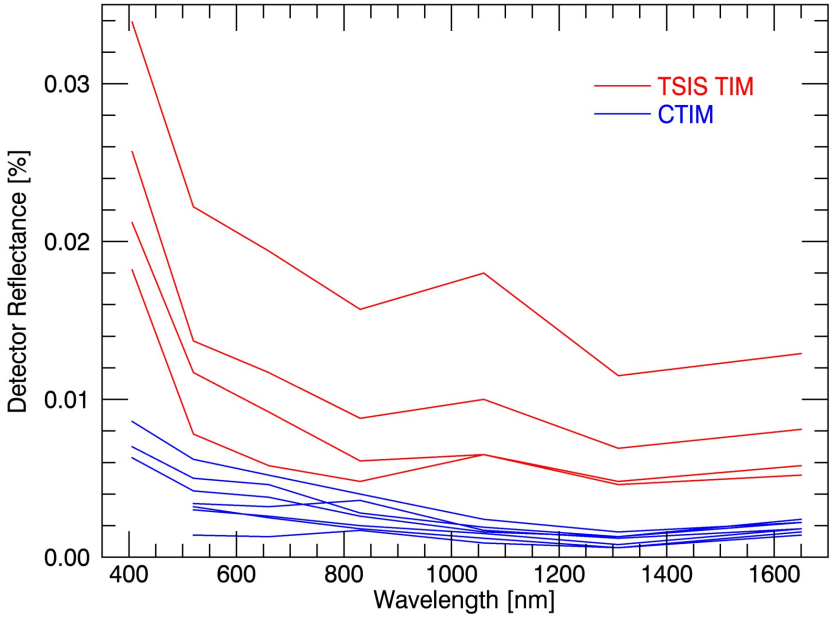
Reflector



CTIM Detector

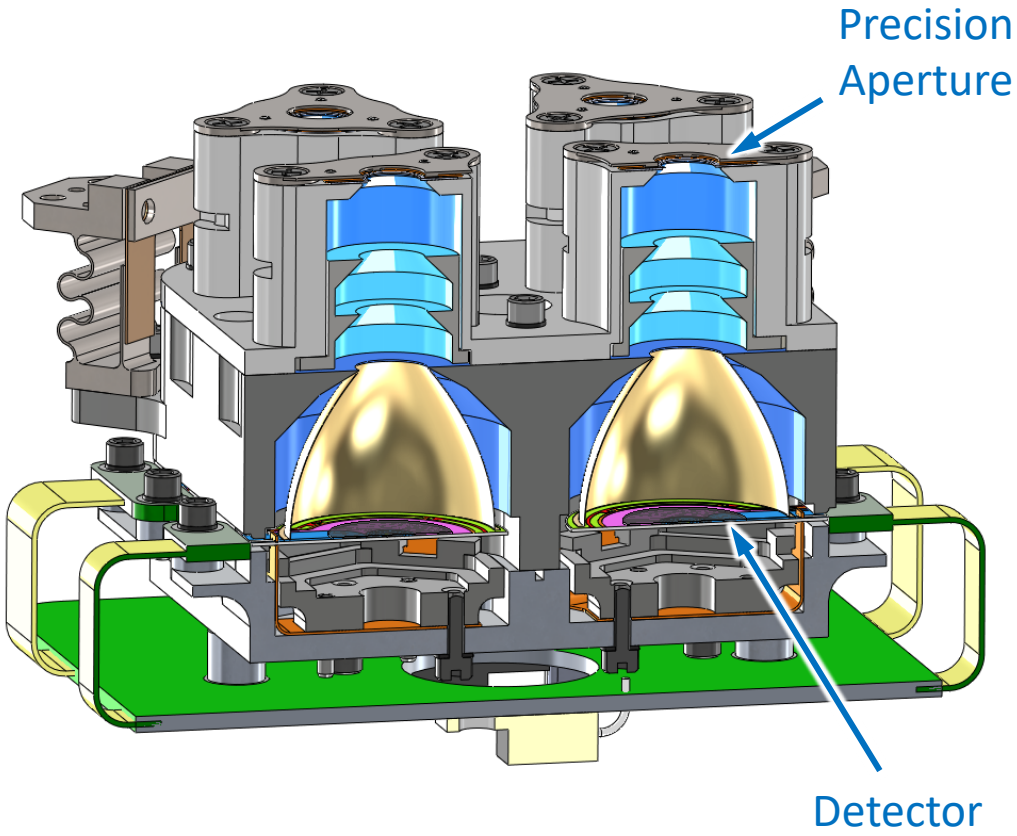
- Thermally integrated reflector
  - Only 51 μm thick
- ~10x darker with reflector
  - Absorbance >99.99%

Detector Reflectance

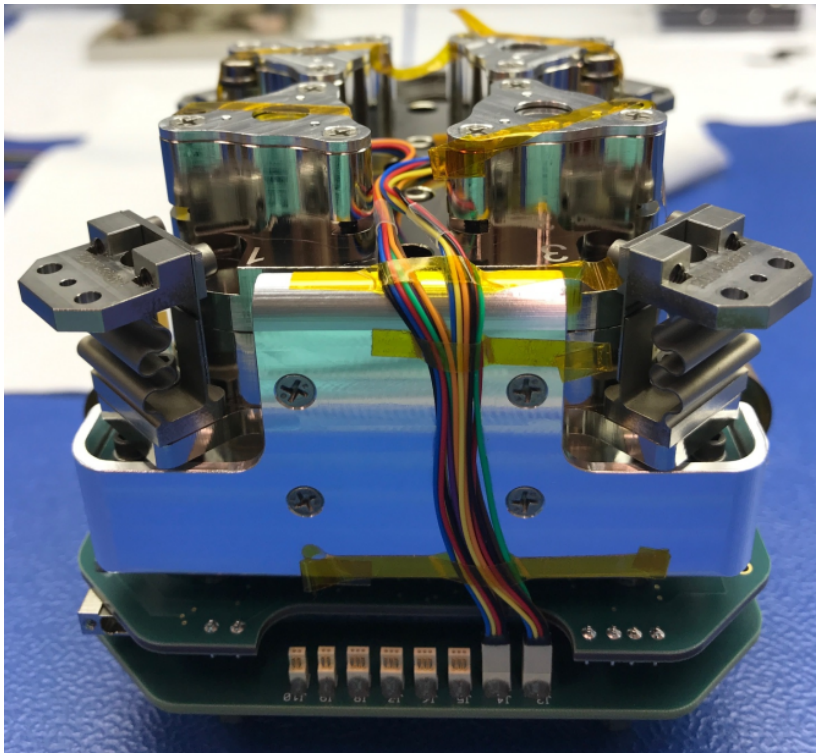


CTIM Detector Head

- Detector head has four channels
  - Redundant channel degradation tracking
- Shutter for each channel



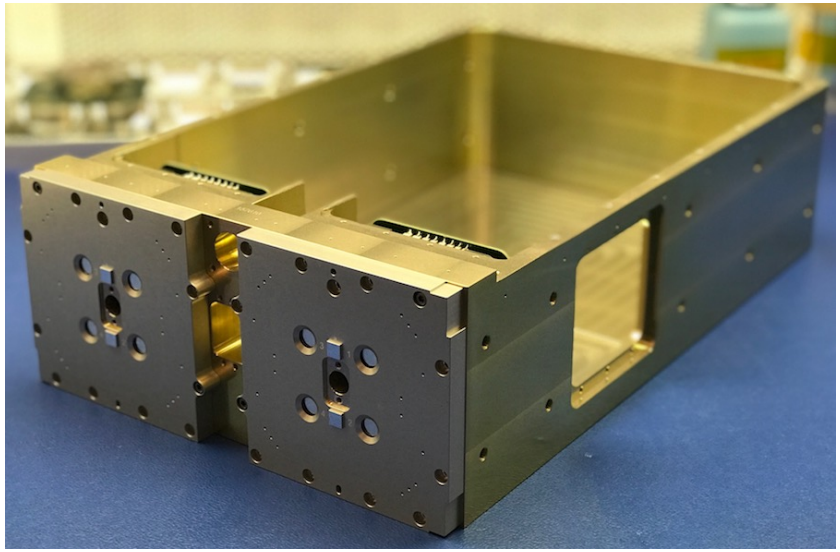
Engineering Detector Head

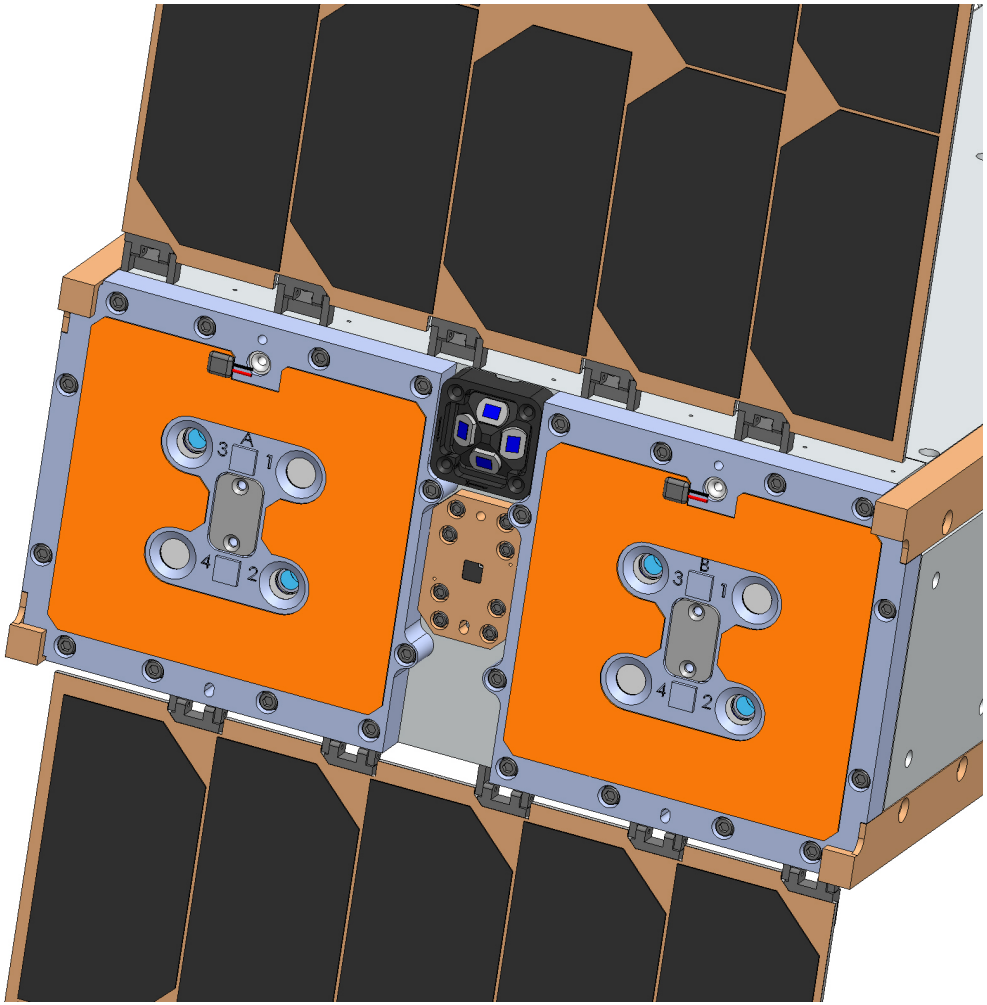


CTIM CubeSat

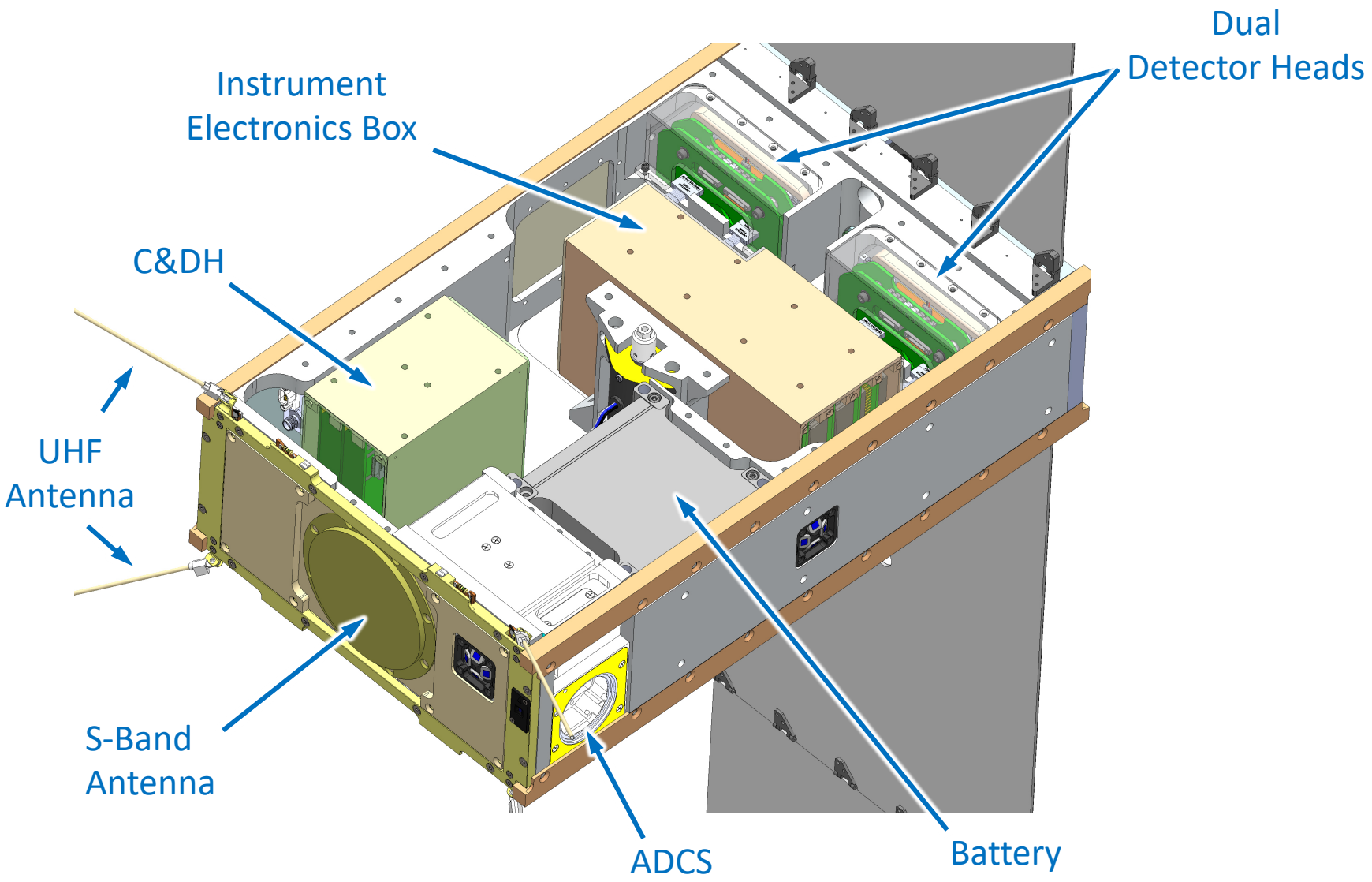
- 6U CubeSat
- Two detector heads
  - Eight channels
  - Extra channels permit better test of on-orbit stability

CTIM Engineering Model



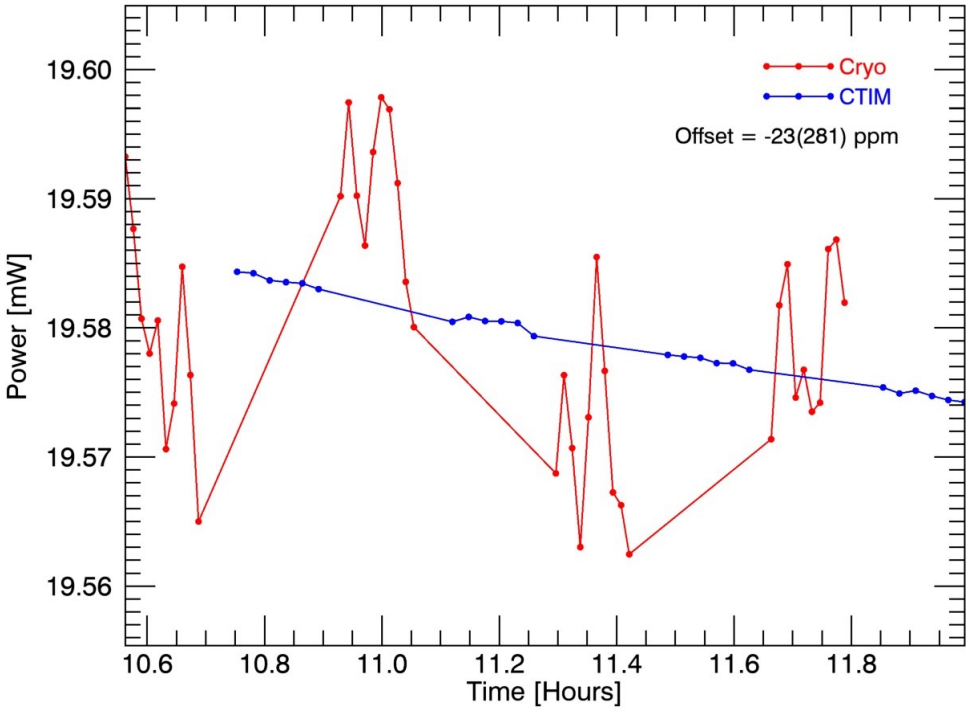


CTIM CubeSat Components

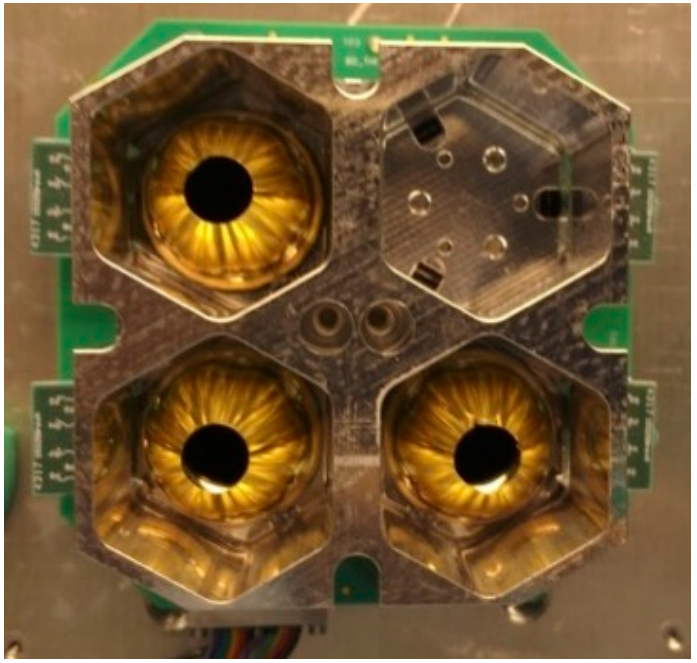


Radiometric Prototype Testing

- Compared prototype CTIM instrument against cryogenic radiometer
  - Channel A difference = 0.029 +/- 0.03%
  - Channel B difference = -0.014 +/- 0.03%
  - CTIM noise < cryogenic radiometer noise

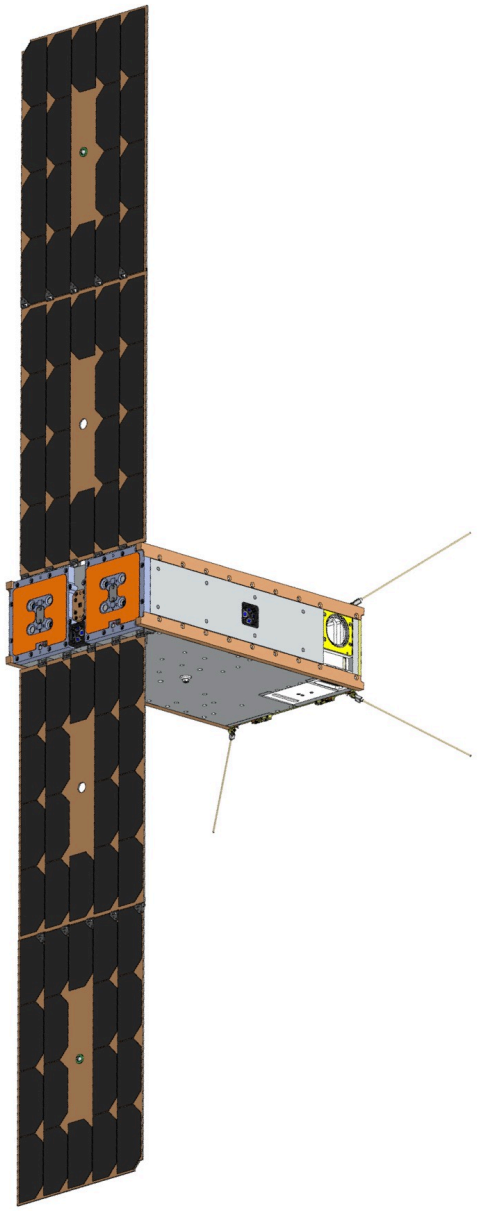


CTIM Prototype



CTIM Mission

- CubeSat design borrows from CSIM
  - Implements lessons learned from CSIM operations
- CTIM EM Instrument is being built now
  - Radiometric and environmental testing this summer
- Flight instrument build this fall
- CubeSat assembly & test spring-summer 2020
- Delivery & launch late 2020
  - Baseline 1 year mission
- Targeting 500km, non-polar orbit
  - Orbital lifetime >3 years
  - Don't fly over the poles if you don't have to!



Future

- CSIM + CTIM in 12U
- Solar irradiance record maintained by continually refreshed constellation of 2-3 12U CubeSats
  - Needed for robustness instead of ground coverage
- Mitigates risk of launch/satellite/instrument failure
  - i.e. Glory launch in 2011
- Permits infusion of new technology